

**Risk Communication in Occupational Health:
Promoting Screening for
Chronic Beryllium Disease**

by

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of the Requirements for the Degree of
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Abstract

Chronic beryllium disease (CBD), a lung disease caused by exposure to beryllium, is a serious occupational health issue. Despite the presence of industries within British Columbia with possible beryllium exposure, many workers are not aware of their risk of developing CBD. The objective of this study was to assess the utility of risk communication to raise awareness of CBD and to promote screening in aerospace workers and dental technicians in BC. Online surveys conducted before and after risk communication evaluated the effectiveness of the communication based on the Precaution Adoption Process Model (PAPM). The recruitment of aircraft maintenance workers was unsuccessful. Fifty completed survey responses were collected from dental technicians. There was a significant tendency for subjects to become concerned about their risk and to consider taking a screening test after the risk communication. Subjects' levels of knowledge, perceived severity, perceived benefits, and self-efficacy were associated with the PAPM stages.

Keywords: beryllium; chronic beryllium disease; risk communication; Precaution Adoption Process Model

Dedication

To my parents and Pat for their unwavering love and support

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1. Introduction

Today's complex use of toxic chemicals in a wide range of occupations has led to growing concern about their potential harm to humans. Despite the fact that in most cases the harm is preventable, chemical exposure risks and their consequent health effects are often dismissed when effective risk communication is lacking. Chronic beryllium disease (CBD), a potentially debilitating lung condition resulting from exposure to beryllium, has been recognized in beryllium manufacturers and primary users in the U.S. since the 1930s (Walsh, 2009). Even in the U.S, hazard recognition is still limited in many downstream industries where beryllium-containing materials are used. Canada is no exception to the lack of public awareness. Despite the presence of several industries with possible beryllium exposure within British Columbia (BC), many workers are not aware of their health risk, and there has been no surveillance for CBD in BC (Takaro, McLeod, Xu, Koehoorn, & Demers, 2009).

A research group at Simon Fraser University, led by Dr. Takaro, is currently conducting an assessment of beryllium disease risk (the "Beryllium Study") in BC industries. This is the first study in BC that performs exposure assessment in workplaces where current or past beryllium exposure is suspected and screens workers at risk for CBD. From my experience in attempting to recruit study participants for the Beryllium Study, I learned that many facility representatives as well as workers are not aware of their possible exposure to beryllium and its health risks, and show little interest in the study. Lack of recognition about the disease is a key factor that has prevented BC from taking action against beryllium exposure and consequent disease risks. There is a need to raise public awareness of the health risks in order to promote screening for CBD and, in the long run, to construct the foundation for successful surveillance programs. This issue formed the basis for this thesis.

2. Background

2.1. Beryllium as a Human Health Hazard

2.1.1. *Beryllium Hazard Identification*

Beryllium (Be) is a naturally occurring alkaline earth metal with its atomic number of four and atomic weight of 9.012182. Beryllium can be extracted from beryl ore in silicate minerals and converted into beryllium hydroxide (Walsh, 2009). The United States Geological Survey estimated that about 65 percent of world beryllium resources are located in the United States, allowing the country to have the largest beryllium mine production in the world (Jaskula, 2012, pp. 28-29). Naturally occurring beryllium exists at low level in Canada, mostly in Yukon-B.C. border and Ontario (Groat, Hart, Lewis, & Neufeld, 2005). However, there is no beryllium mining in current operation in Canada, and Canada's beryllium resources are imported primarily from the United State ("CAREX Canada,2012).

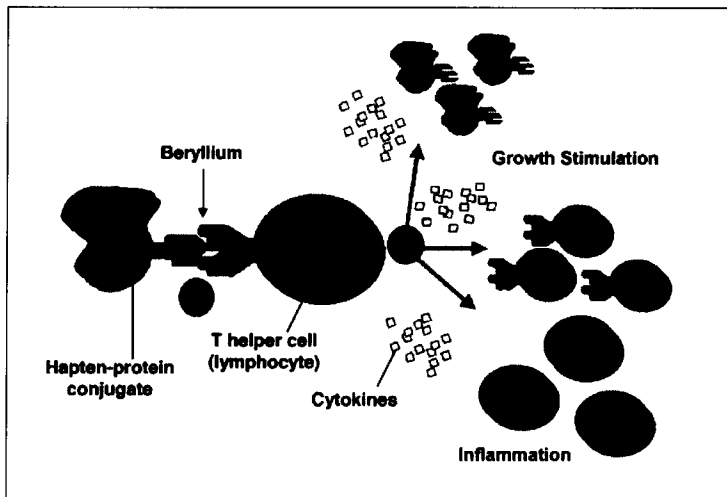
This strong and light-weight metal has an unusually high melting point of 1,287 centigrade and some unique properties such as low density, high electrical and thermal conductivity, oxidation resistance in the air, and its characteristics as neutron reflector and moderator (Brush Wellman, n.d.; Field, 2001; Walsh, 2009). Because beryllium as an alloying metal can harden and strengthen other metals, beryllium-copper, aluminum, and nickel alloys are the most common forms of beryllium use (Walsh, 2009). Beryllium oxide, also known as beryllia, is used in ceramics (Walsh, 2009). Due to its unique physical and chemical properties, beryllium has been used in increasing numbers of industrial and consumer products since 1927 (Field, 2001). Products containing beryllium include, but are not limited to, military equipment, nuclear weapons, aircraft, ceramics, dental crowns and bridges, electronics, golf clubs, bike frames, and jewellery (Christie & Brathwaite, n.d.; Henneberger, Goe, Miller, Doney, & Groce, 2004; Takaro et al., 2009).

2.1.2. Chronic Beryllium Disease

Although it has been used in a wide variety of products, beryllium is highly toxic, and exposure to beryllium is associated with serious adverse health effects. While high levels of exposure can cause acute beryllium disease and are associated with lung cancer (Steenland & Ward, 1991), CBD is the most important health concern at the current occupational beryllium exposure levels.

When individuals are exposed to beryllium dust or fumes by inhalation, ingestion, or dermal contact only some become sensitized to beryllium. Beryllium absorbed by the body binds with hapten-protein conjugates and is recognized as antigen by T lymphocytes where hypersensitivity takes place in susceptible individuals (Figure 1) (Amicosante & Fontenot, 2006; Ponce, Takaro, Bartell, Jabbour, Ertell, Abbotts et al., n.d.). This pre-symptomatic immune system disorder, called beryllium sensitization (BeS), occurs prior to development of CBD.

Figure 1. Mechanism of Beryllium Sensitization and Lymphocyte Proliferation



In some sensitized individuals, the activated T lymphocytes release cytokines which amplify lymphocyte proliferation (Figure 1) (Ponce et al., n.d.). The cell proliferation leads to granulomatous inflammation of the lungs and may result in development of CBD. The prevalence of BeS ranges from one to nineteen percent of exposed workers (Maier, 2002; Saltini, Richeldi, Losi, Amicosante, Voorter, van den Berg-Loonen et al., 2001). There are genetic factors contributing to people's susceptibility to BeS. The

human leukocyte antigen HLA-DPB1 with a glutamic acid at position 69 is associated with beryllium presentation to T cells, which makes it an important marker of susceptibility for BeS (Rossman, Stubbs, Lee, Argyris, Magira, & Monos, 2002; Wang, Farris, Newman, Shou, Maier, Smith et al., 2001).

A longitudinal cohort study conducted by Newman and his colleagues concluded that about six to eight percent of individuals with BeS develop CBD every year, with its latency period ranging from a few months to 40 years (Newman, 2004; Rossman, 2001). However, it is not known whether all beryllium-sensitized individuals eventually will develop CBD (Newman, 2004; Rossman, 2001). Individuals with CBD in early stages may not experience any symptoms and do not require any medication. As the disease progresses, interstitial fibrosis increases and they may experience various symptoms such as shortness of breath, wheezing, dry cough, night sweats, and chest and joint pain. CBD is incurable and is usually treated with corticosteroid therapy to reduce inflammation. However, long-term use of corticosteroid therapy is associated with several side effects, and response to the treatment varies by patient (Sood, Beckett, & Cullen, 2004). CBD is fatal in severe cases. Diagnosis of CBD is problematic because it mimics sarcoidosis, another lung condition of unknown cause that resembles CBD physiologically and histologically. This often times leads to misdiagnosis unless the specific blood test for beryllium sensitization is performed.

2.1.3. *Beryllium Exposure Assessment*

Surface wipe sampling is a method used to measure beryllium dust residues on a surface by wiping the surface with a pre-moistened towelette and analyzing beryllium content in the sample. The U.S. Department of Energy (DOE) set surface levels of concern for beryllium at 0.2 microgram per 100 square centimeter or higher (DOE, 2009, May). Surface wipe sampling is often used as an initial exposure assessment when beryllium contamination of a sampling area is unknown. This method is also suited to investigation of legacy exposures because beryllium dust residues remain on an untouched surface for a long time. However, the wipe sampling method by itself is not sufficient to estimate workers' exposure risks because surface dust contamination levels do not represent exposure levels of inhalable beryllium. Determining a background level

is also a challenge since naturally occurring beryllium from the local environment can travel into a sampling area.

Exposure risk assessment for beryllium is usually based on airborne beryllium measurements using personal air sampler data. The current occupational exposure level (OEL) for beryllium in BC is 2 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) in the air, eight-hour time weighted average. However, a growing number of studies have shown that the current OEL of 2 $\mu\text{g}/\text{m}^3$ is clearly not protective (American Conference of Governmental Industrial Hygienists, 2009; U.S. Environmental Protection Agency, 1979). For example, Kelleher and colleagues (2001) found twenty individuals with BeS in a beryllium machining plant whose lifetime-weighted beryllium exposure levels ranged from 0.024 to 0.6 $\mu\text{g}/\text{m}^3$ (pp. 238-249). Other jurisdictions such as the Canadian Labour Code and American Conference of Industrial Hygienists (ACGIH) set the OEL for beryllium at 0.05 $\mu\text{g}/\text{m}^3$. In 2009, WorkSafeBC announced that the current OEL of 2 $\mu\text{g}/\text{m}^3$ was under review by the WorkSafeBC's OEL Review Committee. (WorkSafeBC, n.d.-a). However, despite over three years under discussion, a new standard has not been set.

Dose-response relationships for BeS and CBD have been controversial issues. Although the exposure regulations are based on beryllium mass concentration, this type of measurement does not always predict the incidence of BeS and CBD well. While some genetic factors are associated with people's susceptibility, characteristics of beryllium exposure such as chemical form, particle number, and particle size and surface area may contribute to dose or more specifically, lung-deposited dose. Kent, Robins and Madle (2001) studied beryllium exposure measurements based on the mass median aerodynamic diameter (MMAD), which is a specific particle diameter at which 50 percent of the mass is larger and 50 percent is smaller (p. 539). The study suggested that mass concentrations of beryllium particles less than 3.5 micrometer MMAD predict the incidence of BeS and CBD better (Kent et al., 2001). Another study, conducted by McCawley, Kent and Berakis (2001), found that beryllium mass concentrations were not correlated with particle number concentrations, and concluded that particle number is more appropriate exposure measurement in understanding the dose-response relationship (p. 631).

One may argue that the prevalence of BeS may only be one percent of beryllium-exposed workers, and lowering the OEL will not make much improvement in workers' health since the current exposure measurement methods used in the OEL are not reliable. However, one percent prevalence of BeS should be considered as high risk given the nature of beryllium hazard. For example, drinking water and air pollution standards used in cancer risk assessment are designed to protect a much lower percentage of individuals at risk such that risk levels are estimated by the prevalence of one in 10,000, 100,000, and 1,000,000 (EPA, 1979). There is a clear causality between exposure to beryllium and BeS, and reducing the exposure levels is a sensible decision. Therefore, by adopting the precautionary principle, lowering the OEL is still recommended until an alternative method for beryllium exposure assessment and dose-response relationship prediction is established.

2.1.4. Populations at Risk

CAREX Canada estimated that there are currently about 4,000 working-age individuals who are exposed to beryllium in their workplaces in Canada (CAREX Canada, 2012). Eighty-six percent of them are male; about 500 of them are in British Columbia (CAREX Canada, 2012). While these estimates count only the current workers with the exposure risk, the actual total number of workers at risk of developing CBD is thought to be much higher since beryllium has been in the market for decades. Among the beryllium-exposed workers in BC, suggested major subpopulations at risk include welders, dental technicians, and those involved in repair and maintenance of vehicles including aircraft (McCaig, 2006). Based on the compiled data from OSHA inspections in the U.S. from 1979 to 1996, all three occupations in BC may have the risk of beryllium exposure at or above $0.1 \mu\text{g}/\text{m}^3$, and even higher than $0.5 \mu\text{g}/\text{m}^3$ in some types of welders, assuming that the exposure levels in these occupations in BC are similar to those observed in the U.S. (McCaig, 2006).

Beryllium alloys have been used in dental prosthesis as less expensive alternatives to gold and silver since the 1970s (Kotloff, Richman, Greenacre, & Rossman, 1993). Beryllium adds hardness, strength and corrosion resistance to alloyed metals and increases castability of crowns and bridges (Bezzon, De Mattos, Ribeiro, & Rollo, 1998; Kotloff et al., 1993). Dental technicians can be exposed to beryllium dust

and fumes when they melt and cast beryllium alloys and sandblast, de-burr and polish the casted frames. WorkSafeBC conducted an exposure assessment in several dental laboratories in BC between 1982 and 1992, although there is no formal report of this assessment available to the public. The results of 20 samples provided by Geoffrey Clark, Senior Occupational Hygienist at WorkSafeBC, ranged from 0.1 to 111 $\mu\text{g}/\text{m}^3$ of beryllium; 12 of them were at or above the current OEL of 2 $\mu\text{g}/\text{m}^3$ (G. Clark, personal communication, June 25, 2012). These data support the need for further investigation in dental laboratories and proper communication with former and current dental technicians in BC.

The aerospace industry also takes advantage of the unique characteristics of beryllium. Beryllium alloys are used in bushing, springs, and electrical connectors, and beryllium oxide is used in electrical insulators in some commercial aircraft (Willis & Florig, 2002). Beryllium exposure can occur during maintenance of the beryllium-containing materials, which makes aircraft maintenance workers at risk of becoming sensitized to beryllium and developing CBD. Some CBD cases reported to the Beryllium Case Registry were due to processing and handling of beryllium compounds in the aerospace industry (Hasan, 1974).

2.1.5. Disease Prevention

Chronic beryllium disease is preventable. Substituting beryllium-free materials for beryllium-containing materials is the best method of eliminating the sources of beryllium exposure and preventing workers from developing BeS and CBD. Engineering and administrative controls may reduce the level of beryllium exposure and number of workers exposed to beryllium. In order to reduce exposure to beryllium dust or fumes, WorkSafeBC recommends that workers should properly use personal protective gear such as an air-purifying respirator, gloves, goggles, face shield, and work clothes, and keep all contaminated items at work (WorkSafeBC, n.d.-b). While these prevention methods as well as periodic education and training are useful to protect workers from exposure to beryllium, it is recommended that workers at risk of exposure to beryllium take a screening test that detects BeS.

2.1.5.1. The Beryllium Lymphocyte Proliferation Test

The beryllium lymphocyte proliferation test (BeLPT) is used specifically for screening for BeS. The BeLPT detects whether an individual is sensitized to beryllium by observing lymphocytes' response to beryllium. In this test, lymphocytes are separated from a blood sample and mixed with a beryllium solution of varying concentrations in vitro. In addition, two positive controls are prepared, one with mitogens and the other with antigens. Normal lymphocytes should proliferate in these controls. After several days of cultivation, the lymphocytes' response to beryllium is determined based on the lymphocyte cell counts. Cell multiplication observed in wells with beryllium solution indicates an abnormal test result, meaning that the individual has abnormal immune response to beryllium.

BeS is confirmed when an individual receives two or more abnormal BeLPT results, and further medical examination is recommended to determine whether the individual has CBD. Because people may become sensitized to beryllium long after the initial exposure, individuals with beryllium exposure history who received normal BeLPT results should repeat the test at least every three years. The periodic testing makes early detection of BeS possible and helps find individuals at risk for CBD prior to the development of the disease. Whether or not a sensitized individual has already developed CBD, elimination of further beryllium exposure and proper medical treatment may prevent or slow the development of CBD. The Beryllium Study, funded by the WorkSafeBC, provides the BeLPTs at no charge to individuals who are suspected of having current or past exposure to beryllium.

2.2. Risk Communication

2.2.1. *Precautionary Advocacy*

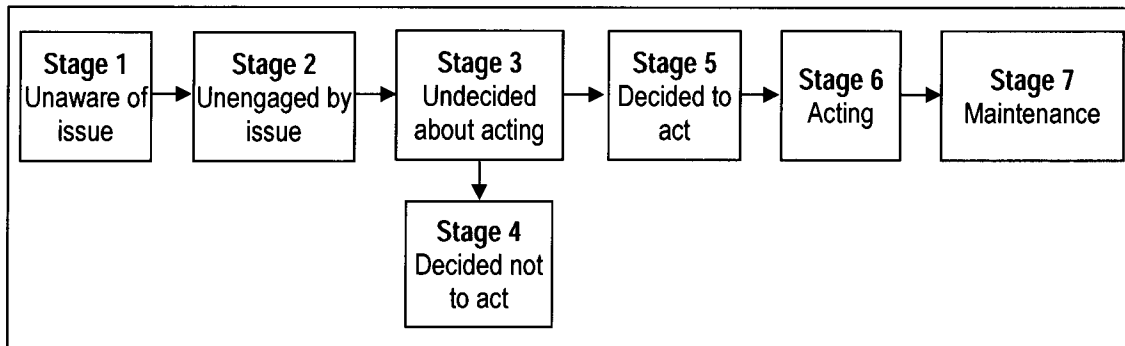
Risk communication advocates the importance of the balance between scientific severity of an issue and the public's perception of the issue. Peter Sandman, a risk communication specialist, defines hazard as how much harm a specific issue likely to do and outrage as how upset it is likely to make people (Sandman, n.d.). He categorizes risk communication into the following tasks: (a) precaution advocacy when hazard is

high and outrage is low, (b) outrage management when hazard is low and outrage is high, and (c) crisis communication when both hazard and outrage are high (Sandman, n.d.) Based on the Sandman’s approach, the current situation of the CBD risk in BC industries is characterized as “high hazard and low outrage,” meaning that people are minimally upset or concerned about the beryllium hazard even though it causes serious health effects and there are an estimated hundreds of workers currently being exposed to beryllium at work. In this scenario, precautionary advocacy is taken to alert insufficiently upset people to the serious risk.

2.2.2. The Precaution Adoption Process Model

The Precaution Adoption Process Model (PAPM) is a stage theory that describes how an individual comes to the decision to adopt a given precaution and proceed to take action. The PAPM explains seven qualitatively distinct stages as shown in Figure 2 (Weinstein, Sandman, & Blalock, 2008, pp. 123-148).

Figure 2. The PAPM Stage Transition



In Stage 1 of the PAPM, people are unaware of an issue and a given precaution. In Stage 2, they have become aware of the issue but are not yet engaged by the issue. Once people are engaged by the issue but have not decided whether to adopt a given precaution, they are in Stage 3, the decision-making stage. People may suspend making a decision and remain in Stage 3; otherwise they proceed to Stage 4 when deciding not to take action or to Stage 5 when deciding to adopt the precaution. Then, the next step for those who have decided to adopt the precaution is to act on the decision, moving to Stage 6. Finally, if relevant, the precaution has been maintained over time in Stage 7.

Dr. Weinstein and his colleagues tested the PAPM in the context of home radon testing as the target precaution (Weinstein, Lyon, Sandman, & Cuite, 1998; Weinstein & Sandman, 1992). The results of the studies showed that the model could effectively categorize people into the PAPM stages by their behavioral differences in home radon testing, and the factors that affect the stage transitions varied by stage (Weinstein et al., 1998; Weinstein & Sandman, 1992). For example, risk vulnerability was a significant factor in getting people to decide to test (Stage 5), while it did not have a significant effect on making those “decided-to-test” people actually conduct radon testing (Stage 6) (Weinstein et al., 1998). On the other hand, detailed information about how to order a radon test kit was less important for those who were undecided, but was a significant factor in the shift from Stage 5 to Stage 6 (Weinstein et al., 1998). The PAPM has been applied to many other types of health behaviors such as exercise and calcium intake for osteoporosis prevention (Blalock, Currey, R. Devellis, B. Devellis, Giorgino, Anderson et al., 2000; Blalock et al., 1996; Sharp & Thombs, 2003), mammograms for breast cancer (Clemow et al., 2000), and red meat consumption during a livestock epidemic (Sniehotta, Luszczynska, Scholz, & Lippke, 2005).

2.2.3. *The Health Belief Model*

While the PAPM describes people’s health-related behaviors by the stage transition theory, the Health Belief Model (HBM) attempts to predict health behaviors by evaluating the following primary factors: perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action, and self-efficacy (Champion & Skinner, 2008, pp.45-66). Perceived susceptibility is a person’s beliefs about the likelihood of getting a disease or condition. Perceived severity is how serious a person thinks it is to contract an illness or leave it untreated. Perceived benefits illustrate one’s beliefs about positive consequences of adopting a particular health behavior, regarding not only the health benefits but also non-health related aspects, such as pleasing family members by receiving a health examination and saving medical costs by preventing an illness. A person may also have perceived barriers against adopting a health behavior. Cues to action are external influences that can trigger one’s action of making a behavioral change. For example, pregnancy may make a mother quit tobacco smoking. Finally, self-efficacy is one’s confidence in making the change.

Dr. Blalock and her colleagues used the PAPM to examine predictors associated with adoption of two health behaviors, calcium consumption and weight-bearing exercise, to prevent osteoporosis in women (Blalock et al., 1996). The predictor variables of their interest included osteoporosis knowledge, all of the HBM primary factors except cues to action, health motivation, controllability, precaution effectiveness, and subjective norms (Blalock et al., 1996). Based on the results of their mailed-out questionnaire completed by 452 premenopausal women, the participants were grouped into different PAPM stages in regard to their intention to increase the amount of calcium consumption and exercise in order to prevent osteoporosis (Blalock et al., 1996). Comparing mean scores of each predictor variable across the stages, they found that all of the variables except perceived severity were associated with calcium stage and eight of the twelve variables were associated with exercise stage (Blalock et al., 1996).

3. Objectives

The main purpose of the risk communication is to educate workers at risk of CBD, while the overall goal in broader perspective is to encourage behavioural changes to prevent and reduce the risk, and to promote screening for CBD by gaining adequate knowledge about the disease. The study proposed in this paper focused on the BeLPT as the target precaution of the PAPM, aiming to learn how effectively risk communication can motivate potentially beryllium-exposed workers to be tested for BeS. Knowledge and the HBM variables were adopted to determine what factors are associated with the workers' transition across the PAPM stages. The study targeted two major populations at risk of exposure to beryllium in BC (McCaig, 2006): aerospace workers and dental technicians. We hypothesized that providing information about beryllium hazard and CBD through risk communication would encourage workers to advance towards the "decided to test" stage, and that factors associated with their transitions in the PAPM would be different across the stages.

4. Methods

4.1. Preparation of Survey and Communication Materials

The conduct of this study consisted of pre-intervention survey, risk communication, and post-intervention survey, targeting aerospace workers and dental technicians in BC.

4.1.1. *The Pre-Intervention Survey*

The following three types of questions were asked in the pre-intervention survey: demographic information, the PAPM stages, and the knowledge and HBM variables (Table 1). First, the pre-intervention survey had questions about participants' age, sex, race or ethnicity, workplace location, and education level. These variables were analyzed to study the characteristics of the study populations and to determine whether these variables are associated with the PAPM stages and the knowledge and HBM variables.

Second, we intended to classify study subjects in Stage 1 through Stage 5 of the PAPM based on their pre-intervention survey responses. Subjects are in Stage 1 if they have never heard about beryllium hazard or have heard about it but know nothing about it. Subjects are in Stage 2 if they have some knowledge about beryllium hazard but have never thought about being tested for CBD. Once they are engaged by the health issue but are undecided about being tested, they are in Stage 3, the decision-making stage. Some people may remain in Stage 3; otherwise they proceed to Stage 4 when deciding not to take the test or to Stage 5 when deciding to take the test. The survey also asked whether a subject has ever taken the BeLPT (Stage 6) and intent to repeat the test again in the future (Stage 7) in order to understand the study populations, although I suspected that only a few or none of the subjects were in Stage 6 or 7.

Table 1. Pre-Intervention Survey Questionnaire Variables and Descriptions

Question Type	Description
Demographic Information	Age, sex, race/ethnicity, workplace location, and education level
The PAMP stages	
• Stage 1	A subject is unaware that beryllium is a human health hazard
• Stage 2	A subject is aware of the issue but has never thought about being tested for CBD
• Stage 3	A subject has thought about the issue but is undecided about being tested for CBD
• Stage 4	A subject has decided not to be tested for BeS
• Stage 5	A subject has decided to be tested for BeS
Knowledge and HBM variables	
• Knowledge	Ten true or false questions that ask about general information about beryllium and CBD
• Perceived susceptibility	How likely a subject thinks it is that s/he has been exposure to beryllium, and how concerned s/he is about being at the risk of BeS and CBD
• Perceived severity	How serious a subject thinks it is to become sensitized and to develop CBD
• Perceived benefits	In what degrees a subject agrees with the benefits of taking the BeLPT
• Perceived barriers	In what degrees a subject agrees with the negative aspects of taking the BeLPT
• Self-efficacy	How confident a subject feels that s/he has enough information to make a decision of being tested and know how to take the BeLPT

At last, the pre-intervention survey had questions about the knowledge and HBM variables as described in Table 1. Subjects' levels of knowledge about beryllium hazard and CBD were determined by ten true or false questions. A response option of "don't know" was also given for each of the knowledge questions. There are four perceived susceptibility questions. The first two asked subjects their expectation of beryllium exposure likelihood in current and past workplaces, with the response choices of very likely, somewhat likely, somewhat unlikely, very unlikely, and don't know. Two other perceived susceptibility questions asked how concerned the subjects are about their BeS and CBD risks, with choices of very concerned, somewhat concerned, not so concerned, not concerned at all, and don't know. Two perceived severity questions asked how serious the subjects think BeS and CBD are, and their response choices are: very serious, somewhat serious, not so serious, not serious at all, and don't know. A five-point scale of strongly agree, somewhat agree, neither agree nor disagree,

somewhat disagree, and strongly disagree, and don't know option were used for three perceived benefits, three perceived barriers, and two self efficacy questions in response to taking the BeLPT. The specific benefits in question are to know whether a subject has BeS and needs treatment, and to have his or her family supporting the subject getting tested. On the other hand, perceived barriers included time required for the test, discomfort from blood collection, and possible impacts on a subject's employment. Self-efficacy was measured by asking whether a subject has enough information to decide and knows how to get tested. This study did not assess effects of cues to action, the other primary construct of the HBM, because this variable is thought to be associated with the transition from Stage 5 to Stage 6 (Weinstein et al., 1998), which was beyond the scope of this study.

4.1.2. Risk Communication

The educational materials for risk communication in this study contained information about beryllium hazards, CBD, and the BeLPT, specifically focusing on the importance of understanding BeS and why the BeLPT is beneficial to beryllium-exposed workers. The information was gathered mainly by a literature search and by consulting a beryllium education and training team at National Jewish Health in Denver, CO, one of the premier centres for CBD diagnosis and treatment. The communication materials were arranged in seven pages (Appendix B). Page 1 introduced basic information about beryllium and examples of beryllium use including aircraft, automobile, and dental prosthesis. Page 2 described the beryllium exposure pathways, CBD, and its diagnostic confusion with sarcoidosis. They also noted that an individual has risk of developing CBD even when the exposure level is below the current OEL for beryllium in BC ($2 \mu\text{g}/\text{m}^3$). Next, the disease development process including BeS was described on Page 3. This section explained that some but not all beryllium-exposed individuals become sensitized and there may be a long latency period before developing CBD and experiencing disease symptoms.

Page 4 of the risk communication explained that CBD is preventable and treatable but not curable and showed that treatments for CBD can vary from no treatment required to steroids and oxygen therapy depending on the severity of the disease. Page 5 showed how the BeLPT is done and its test result is interpreted, with

advice that a normal test result does not mean it is safe to work with beryllium. Page 6 introduced a case of a dental technician who was diagnosed with CBD thirteen years after her initial exposure to beryllium. The case report illustrated how routine testing is important to prevent or slow the progression of CBD. Finally, Page 7 explained that all individuals who have ever been exposed to beryllium can benefit from taking the BeLPT due to its ability to detect BeS prior to development of CBD. This page also included the Beryllium Study's website link and a researcher's contact information so that subjects can ask for more details about CBD and how to get tested for CBD.

4.1.3. *The Post-Intervention Survey*

The post-intervention survey was developed to ask the same types of questions used in the pre-intervention survey, except the demographic information. The survey also included questions that asked participants about their satisfaction with and feedback on the survey and risk communication materials. The pre- and post-intervention survey questionnaires are attached in Appendix A.

4.1.4. *Survey Instrument*

The online survey and risk communication were constructed using FluidSurveys, a Canadian online survey application. With this application, I created a single study instrument that included a study consent form with study information, pre-intervention survey, risk communication educational materials, and post-intervention survey. The only benefit offered to study subjects was education about beryllium hazards and information about the diagnostic test, and there was no financial compensation paid for study participation. Taking part in the study was voluntary and anonymous. Once the survey link was clicked, Study Information and Consent appeared on the first page, where viewers were asked to read the study information and click "continue" to consent or "exit" to leave the study. Subjects were free to refuse to answer any questions asked in the surveys and withdraw from the study at any time without penalty. It takes approximately fifteen minutes to complete the entire survey and risk communication module. Subjects were allowed to save their incomplete survey and return to complete it later.

Results of the surveys were stored in FluidSurveys' secure online data file, which resides on Canadian servers. Only the Principal Investigator had access to the original data in the online server. Once the surveys were closed, an auto-generated sample code was assigned to each respondent when extracting the data from the server for analysis. The data stored in the online server was discarded after the data extraction. The extracted data was kept electronically in an encrypted data file in the investigator's password-protected computer. Separately from the electronic data, print copies of the data were stored in a different cabinet with a lock for which only the investigator had an access key. All collected data will be kept for a period of two years and will be disposed of in the year 2014.

4.2. Recruitment

Because workers in aerospace and dental laboratories had distinct structural systems, I used different approaches to try to recruit study subjects from the two populations.

4.2.1. *Aerospace Workers*

A list of aerospace companies in BC where beryllium use is suspected was prepared by consulting with WorkSafeBC. The target companies were involved in operation and maintenance of aircraft, including commercial passenger airplanes, helicopters, and seaplanes. Then, I attempted to contact each company's safety manager or operations manager by phone and/or email, and explained about the study and the potential risk of beryllium exposure. This recruitment was done as part of the Beryllium Study. If a company wished to participate in the study, I intended to obtain consent from the manager and arrange the online survey for workers who agreed to participate. Paper copies of the questionnaires and risk communication materials could also be prepared depending on the workplace's or individual's accessibility to the Internet.

4.2.2. Dental Technicians

The College of Dental Technicians of BC (CDTBC) regulates the profession of Dental Technology in British Columbia, and approximately 1,200 dental technicians are currently registered in the CDTBC. The email invitation to the online survey was sent on June 12, 2012 to all of the current practicing registrants of the CDTBC for whom the College had an email address on file. Reminder emails were sent by the CDTBC to all of the email accounts on July 17 and August 2, notifying recipients of the survey's closing date, August 10. The email list was not available to the general public. I did not have access to the CDTBC's email list nor to the email addresses of the participating subjects. Subjects were asked to contact me directly if they wished to receive additional information about the study or the BeLPT. Since the invitation email was sent to individual registered dental technicians regardless of whether they were employed or self-employed, permission for conduct of this study was not obtained from their employers. The online surveys lasted for two months after the initial email was sent by the CDTBC.

4.3. Data Analysis

The subjects who submitted their responses at the end of the online surveys were categorized in Complete group, and those who answered some questions and saved their responses but did not submit were categorized in Incomplete group. The study populations' characteristics were evaluated based on the demographic information provided in the pre-intervention survey. The demographic variables were compared between Complete and Incomplete groups in order to speculate whether any factors were associated with the subjects' participation. Only the survey responses from subjects in the Complete group were considered in further data analysis, and those in the Incomplete group were excluded.

Using simple descriptive statistics, distributions of the subjects across the PAPM stages in pre- and post-intervention periods was observed. Then the five PAPM stages were re-categorized into binary groups: one for those who were unengaged by the beryllium issues (Stages 1 and 2) and the other for those who were engaged by the

issues (Stages 3, 4 and 5). The subjects' stage shifts between pre- and post-intervention periods were analyzed by matched pair samples test. I used the results of the analyses of the PAPM stage changes as a measure of effectiveness of the risk communication on raising the CBD awareness and promoting the BeLPT. The Wilcoxon signed rank tests were conducted to analyze changes in the knowledge and HBM variables' responses between pre- and post-intervention periods, which described how subjects' knowledge and belief changed after learning about CBD and the BeLPT.

Second, I examined the association between the six knowledge and HBM variables and the PAPM stages. A paired two-sample t-test was used to determine the association between the raw knowledge test scores and the binary PAPM stages. The questionnaires contained more than one question for each of the five HBM variables. The associations between each question's responses and the binary PAPM stages were analyzed by the Wilcoxon signed rank tests. I considered all "don't know" responses as missing data in this analysis in order to make the HBM variables valid as ordinal variables. Finally, the subjects' levels of satisfaction with their participation materials were reported to evaluate the survey design and contents.

5. Results

5.1. Study Population

5.1.1. Aerospace Workers

Seventeen aerospace companies in BC were contacted by phone and/or email (Table 2), and none of them agreed to participate in this study.

Table 2. List of Aerospace Companies Contacted

Avcorp	Harbor Air	Pacific Coastal
Aveos	Helijet	Penta (FBO Contractor)
BCIT, School of Transportation	Landmark Aviation (FBO)	Seair
Canadian Helicopters	London Air Services	Vector Aerospace
Cascade	Lindair	WestJet
Esso Avitat (FBO)	Million Air (FBO)	

The followings describe the process of contacting company representatives and their responses. The recruitment was done as part of the Beryllium Study.

5.1.1.1. Avcorp

I called Avcorp's general contact number and left a message to find who would be the person to talk to about the Beryllium Study. There was no response, so I contacted the Vice President, Operations and was directed to the Senior Employee Relations Specialist. When I finally reached him after several phone calls, he agreed to share the study information with the VP of operations and other personnel and to discuss whether they would participate. One company's representative shared his suspicion of beryllium use in some bushings in the past, but the company refused to participate in the study after consulting its safety committee (W. Flaherty, personal

communication, March 2, 2011). The reason for the refusal was simply because this was not one of their top priorities.

5.1.1.2. Aveos

Aveos is a private company contracted by Air Canada since 2004 for its aircraft maintenance activities. First, I called the Aveos' Vancouver office and was directed to its facility team leader, who was not available and did not respond to my voice message. Although four additional phone calls were made, including a message left by Dr. Takaro, the facility leader did not respond to any of the messages. When I reached him at the fifth call, I was told to contact a shop technician. Five phone calls were made to the shop technician including three voice messages left, but he did not respond to any of my calls.

After experiencing difficulty reaching Aveos, I contacted Trustee and Conductor/Sentinel of the International Association of Machinists and Aerospace Workers (IAM) Canadian Airways Lodge 764, whom I met at the BC Federation of Labour Convention. At the first conversation I had with the Trustee, he mentioned that Aveos used and manufactured beryllium-containing bushings on their aircraft (S. Daechsel, personal communication, February 28, 2011). However, the Corporate Industrial Hygienist and Health and Safety Manager found that the Vancouver facility no longer operated the manufacturing and maintenance of the parts (L. Robitaille-Sama, personal communication, August 15, 2011). When Dr. Takaro and I had a teleconference meeting with the IAM Trustee and the industrial hygienist, we explained the potential risk of exposure during disassembling and installation of the beryllium-containing materials and also from the legacy exposures. According to a machinist who had worked for Aveos for over twenty years, the Vancouver facility stopped the manufacturing and maintenance operation over ten years ago and they have done only shipping and installation of the parts since then (S. Daechsel, personal communication, December 6, 2011). The IAM Trustee said the Union supported further investigation, and he brought the topic to Aveos' health and safety committee meetings several times. However, Aveos made a decision not to participate in this study.

5.1.1.3. BCIT, School of Transportation

The Associate Dean, Aerospace was aware of the health risks of beryllium and told me that beryllium is in the bifilar vibration dampers in the S 76 rotor that has been displayed statically for viewing only (G. Turner, personal communication, November 1, 2010). Beryllium exposure from this source is minimal and there is no other beryllium on the campus, while Turner advised instructors to exercise appropriate caution. No further communication has been made with BCIT.

5.1.1.4. London Air Services

The Director of Maintenance of London Air Services showed interest in the Beryllium Study, although he was not aware of any beryllium use in his facility. He contacted Bombardier, a company in the U.S.A. where London Air Services send its aircraft for heavy maintenance, and found that beryllium-copper could be used in bushings on horizontal stabilizers and landing gears (C. Lacroix, personal communication, December 10, 2010). However, London Air Services do not perform any direct maintenance work on the parts suspected to be beryllium-containing. Lacroix thought that the amount of beryllium exposure is minimal if any, and he was reluctant to continue the investigation that required further involvement with Bombardier.

5.1.1.5. Other Companies

I introduced the Beryllium Study information to the other companies' representatives by phone and emails and requested their participation in the Beryllium Study. Cascade, Harbor Air, Helijet, Lindair, Seair, and Vector Aerospace refused to participate in the Beryllium Study either because they were not aware of any beryllium use or simply because they were not interested in the study. I withdrew WestJet from the list of target companies because WestJet does not have a maintenance facility in BC. Canadian Helicopters, Esso Avitat, Landmark Aviation, Million Air, and Penta were also contacted by phone with help from the study's program coordinator, but we did not receive any responses from these companies.

5.1.2. Dental Laboratories

The initial email invitation to the online survey was sent by the CDTBC to 935 email accounts on June 12, 2012; eight emails were returned to the sender as undeliverable due to the recipient's email account failures or rejections. Reminder emails were sent by the CDTBC to all of the email accounts on July 17 and August 2, notifying of the survey's closing date. When the survey was closed on August 10, about two months after the initial email invitation, I had received 50 completed and 24 incomplete responses. The response rate was 5.4 percent, or 50 completed survey responses per 927 successfully delivered emails.

Table 3 describes the demographic characteristics of the study subjects in the dental technician population. Age, sex, race, education, starting year of dental technician career, and work location were compared between the subjects who completed the survey and those who did not. A two sample t-test was used for the age comparison ($p = 0.58$), and the Chi-square test for the sex comparison ($p = 0.59$). Race and work location were categorical variables. Some of the category counts of these two variables were less than five; therefore, the Fisher's exact test was used to compare the Complete and Incomplete groups ($p = 0.61$ for race; $p = 0.34$ for work location). Education and starting year of dental technician career were considered numerical variables (Table 3 only shows the distributions in interval categories). These two variables were analyzed using the Wilcoxon signed rank sum test to accommodate their non-normal distributions ($p = 0.09$ for education; $p = 0.73$ for start year of DT). As a result, none of the six demographic variables had significant difference between the Complete and Incomplete groups, at 95 percent confidence level. No subject reported a diagnosis of CBD or sarcoidosis. It is not know whether the study subjects represent the general population of dental technicians in BC because no demographic information on the population was available.

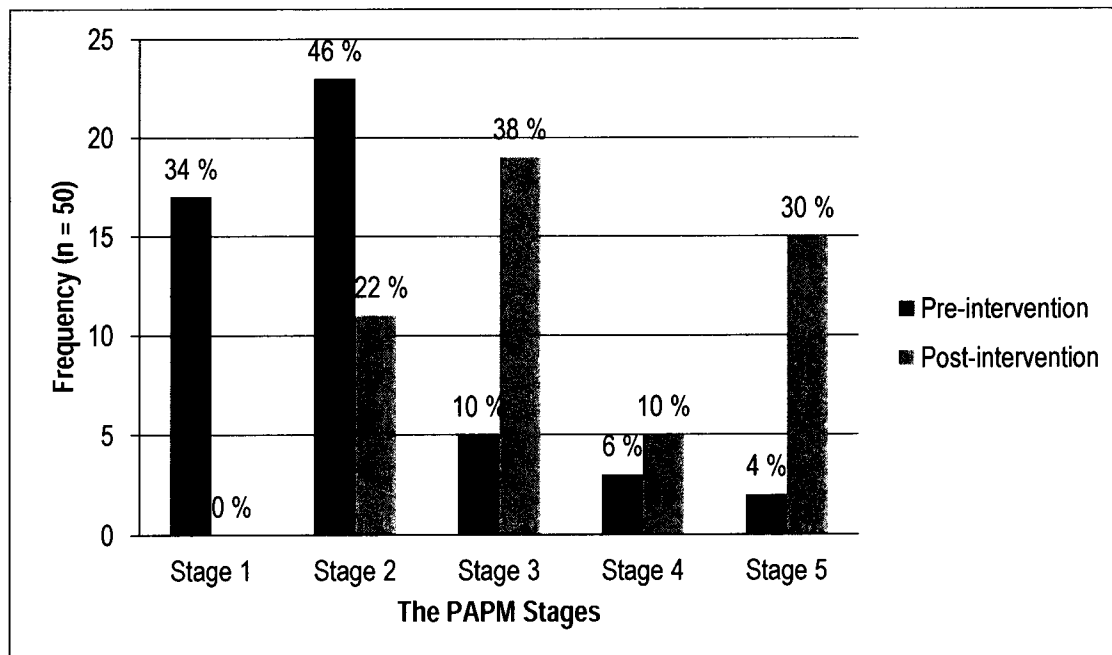
Table 3. Demographic Characteristics of the Study Subjects – Dental Technicians

	Complete (%)	Incomplete (%)	Comparison
Total	50 (100)	24 (100)	
Age			P = 0.5849
20 – 39	8 (16.0)	3 (12.5)	(Two sample t-test)
40 – 59	28 (56.0)	14 (58.3)	
60 – 79	13 (26.0)	4 (16.7)	
Sex			P = 0.6090
Male	34 (68.0)	17 (70.8)	(Chi-square test)
Female	16 (32.0)	6 (25.0)	
Race / Ethnicity			P = 0.1439
White (non-Hispanic)	36 (72.0)	12 (50.0)	(Fisher's exact test)
Black (non-Hispanic)	0	0	
Hispanic	0	1 (4.2)	
Asian	11 (22.0)	9 (37.5)	
First Nations	0	0	
Other	3 (6.0)	2 (8.3)	
Education in year			
12 or less	11 (22.0)	1 (4.2)	(Wilcoxon signed rank test)
13 – 14	12 (24.0)	7 (29.2)	
15 – 16	18 (36.0)	11 (45.8)	
17 or more	8 (16.0)	5 (20.8)	
Start year of DT			P = 0.7283
1960s or before	8 (16.0)	1 (4.2)	(Wilcoxon signed rank test)
1970s	12 (24.0)	5 (20.8)	
1980s	9 (18.0)	9 (37.5)	
1990s	9 (18.0)	5 (20.8)	
2000s or later	7 (14.0)	2 (8.3)	
Work location			P = 0.3397
Metro Vancouver	19 (38.0)	10 (41.7)	(Fisher's exact test)
Lower Mainland outside of Metro Vancouver	13 (26.0)	6 (25.0)	
Victoria	10 (20.0)	3 (12.5)	
Other area of Vancouver Is. / Lower Mainland	3 (6.0)	3 (12.5)	
In BC but none of the above	5 (10.0)	0	
Outside of BC	0	1 (4.2)	

5.2. The PAPM Stages

Association between the PAPM stages and each of the demographic variables was tested to determine whether there were any confounding factors, but none of the variables had individual associations with the PAPM stages. Figure 3 shows the PAPM stage distributions at the two time periods: pre-intervention and post-intervention. At the pre-intervention period, Thirty-four percent of the subjects did not have knowledge about beryllium hazard and CBD. Forty-six percent had some knowledge but had never thought about taking the screening test. The stage distributions shifted to higher levels after reading the risk communication materials. Thirty-eight percent of the subjects had considered taking the screening test but had not decided; total 40 percent had decided whether to take the test.

Figure 3. *Comparison of the PAPM Stage Distributions between Pre- and Post-Intervention Periods*



In order to statistically analyze the stage transitions, the five PAPM stages were re-categorized into binary groups. Stages 1 and 2 were combined into “Unengaged” group, in which subjects were unaware of beryllium hazard or had some knowledge about it but never thought about getting tested for CBD. Stages 3, 4 and 5 were

combined into “Engaged” group, in which subjects had some knowledge about CBD and had considered getting tested for CBD.

Table 4. Transition across the Binary PAPM Stages from Pre- to Post-Intervention Periods

Frequency (n = 50)		Post-int.			McNemar's test
		Unengaged	Engaged	Total	
Pre-int.	Unengaged	9	31	40	P < 0.0001
	Engaged	2	8	10	
	Total	11	39	50	

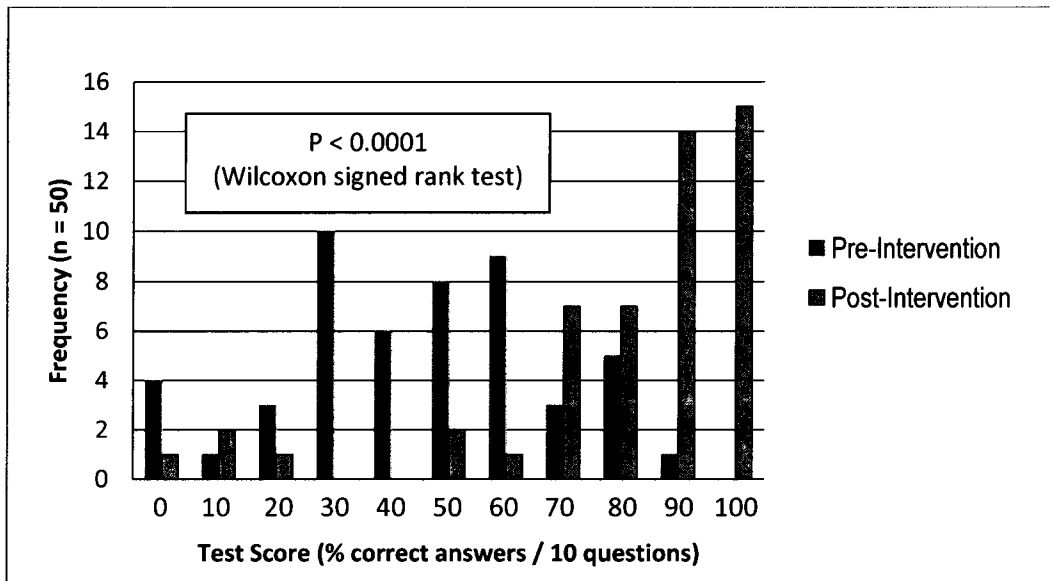
Table 4 shows that 40 subjects were unengaged at the pre-intervention period, but 31 of them became engaged after the risk communication. These responses were dependent samples collected from the same population at different time periods. Because one of the cell counts was less than five, McNemar’s test was used to study whether the transition across the binary PAPM stages was significant. The p-value of less than 0.0001 suggests there was a significant tendency for subjects to become engaged regarding their CBD risk and had taken the BeLPT into consideration after learning about the disease (Table 4).

5.3. Knowledge and HBM Variables

5.3.1. Knowledge

Test scores of the ten true or false questions were compared between the pre- and post-intervention periods to study whether the online risk communication raised subjects’ knowledge levels about CBD. The Wilcoxon signed rank test was used because the two data sets were from the same population and distribution of the test scores at the post-intervention period was not normal. In this analysis, “don’t know” responses were considered as incorrect answers. As shown in Figure 4, the test scores in percentage at the post-intervention period were significantly higher than those at pre-intervention period ($p < 0.0001$), indicating that the online risk communication session could raise the subjects’ levels of knowledge about CBD.

Figure 4. Comparison of the Knowledge Distributions between Pre- and Post-Intervention Periods



5.3.2. Perceived Susceptibility

The five HBM variables were also compared between the pre- and post-intervention periods. The first variable is perceived susceptibility. Table 5 shows the frequency of responses to the four perceived susceptibility questions and results of the Wilcoxon signed rank tests that compared the pre- and post-intervention periods. These tests analyzed the data set of each subject's paired responses (pre- and post-interventions) in the four or five point scale. The "don't know" responses were excluded, and only the matched-paired responses were used in the analyses. The response frequencies shown on Table 5 are the direct counts of the responses and are not matched-pairs by subjects. The sample size of each test is based on the number of matched pairs and does not correspond with the total numbers of responses to each question.

According to the frequency table for the first two items, I observed that the tendency for subjects to report exposure to beryllium was more likely in their past jobs (perceived susceptibility 1) than their current job (perceived susceptibility 2). Approximately half of the subjects were somewhat concerned or very concerned that they might have become sensitized to beryllium (perceive susceptibility 3) and develop CBD (perceived susceptibility 4) at the pre-intervention period.

Table 5. Comparison of Perceived Susceptibility between Pre- and Post-Intervention Periods

Question	Response options	Pre-int.	Post-int.	Wilcoxon signed rank test
Perceived Susceptibility 1: <i>How likely is it that you have been exposed to beryllium dust or fumes in your <u>current</u> job?</i>	Very unlikely	20	20	P = 0.5313 (n = 37)
	Somewhat unlikely	7	5	
	Somewhat likely	12	12	
	Very likely	4	6	
	Don't know	7	3	
	Total	50	46	
Perceived Susceptibility 2: <i>How likely is it that you are exposed to beryllium dust or fumes in any of your <u>past</u> jobs?</i>	Very unlikely	10	9	P = 0.5938 (n = 38)
	Somewhat unlikely	6	3	
	Somewhat likely	9	10	
	Very likely	18	22	
	Don't know	7	1	
	Total	50	45	
Perceived Susceptibility 3: <i>How concerned are you that you might have become sensitized to beryllium?</i>	Not concerned at all	8	5	P = 1.0000 (n = 40)
	Not so concerned	13	13	
	Somewhat concerned	16	20	
	Very concerned	7	8	
	Don't know	5	0	
	Total	49	46	
Perceived Susceptibility 4: <i>How concerned are you that you might develop chronic beryllium disease?</i>	Not concerned at all	9	5	P = 0.9872 (n = 44)
	Not so concerned	13	12	
	Somewhat concerned	15	21	
	Very concerned	11	8	
	Don't know	2	0	
	Total	50	46	

None of the four items had a statistically significant difference in subjects' responses between the pre- and post-intervention periods, indicating that the subjects' perceived susceptibility about CBD did not change after the risk communication.

5.3.3. Perceived Severity

There were two perceived severity questions: one for BeS and the other for CBD. Twenty-nine out of 50 subjects considered BeS somewhat serious or very serious at the pre-intervention period (Table 6). The number increased to 43 at the post-intervention

period, and the Wilcoxon signed rank test showed that the increase in perceived severity about BeS was significant ($p < 0.01$). The vast majority of the subjects already had high perceived severity about CBD at the pre-intervention period, and their belief did not change significantly after the risk communication ($p = 0.29$). Sixteen subjects answered “don’t know” about severity of BeS, while seven answered “don’t know” regarding CBD at the pre-intervention period. I suspect that the study subjects had less recognition of BeS than that of CBD. However, there was no “don’t know” response to both questions at the post-intervention period, suggesting that the risk communication provided the subjects sufficient information to become aware of how serious BeS and CBD are.

Table 6. Comparison of Perceived Severity between Pre- and Post-Intervention Periods

Question	Response options	Pre-int.	Post-int.	Wilcoxon signed rank test
Perceived Severity 1: <i>How serious do you think sensitization to beryllium is?</i>	Not serious at all	1	0	P = 0.0063 (n = 31)
	Not very serious	4	3	
	Somewhat serious	16	13	
	Very serious	13	30	
	Don't know	16	0	
	Total	50	46	
Perceived Severity 2: <i>How serious do you think chronic beryllium disease is?</i>	Not serious at all	1	0	P = 0.2852 (n = 39)
	Not very serious	0	1	
	Somewhat serious	11	6	
	Very serious	30	39	
	Don't know	7	0	
	Total	49	46	

5.3.4. Perceived Benefits

Two of the three perceived benefits items had significant differences between the pre- and post-intervention periods; p-value of 0.01 for the benefit of a BeS diagnosis and p-value of 0.02 for determining whether treatment is necessary (Table 7). In other words, after the risk communication, more subjects reported the BeLPT would be beneficial to determine whether they have BeS and whether treatment is necessary. Their perceived benefits regarding family support for getting tested for BeS did not have a significant difference between the pre- and post-intervention periods ($p = 0.27$).

Table 7. Comparison of Perceived Benefits between Pre- and Post-Intervention Periods

Question	Response options	Pre-int.	Post-int.	Wilcoxon signed rank test
Perceived Benefits 1: <i>Getting myself tested would let me know if I'm sensitized to beryllium.</i>	Strongly disagree	0	0	P = 0.0098 (n = 42)
	Somewhat disagree	2	0	
	Neither agree nor disagree	5	5	
	Somewhat agree	13	8	
	Strongly agree	26	33	
	Don't know	4	0	
	Total	50	46	
Perceived Benefits 2: <i>Getting myself tested would help me know if I should get treatment.</i>	Strongly disagree	0	0	P = 0.0232 (n = 42)
	Somewhat disagree	1	0	
	Neither agree nor disagree	6	5	
	Somewhat agree	14	8	
	Strongly agree	25	33	
	Don't know	3	0	
	Total	49	46	
Perceived Benefits 3: <i>My family would be supportive of my getting tested.</i>	Strongly disagree	1	1	P = 0.2686 (n = 43)
	Somewhat disagree	0	1	
	Neither agree nor disagree	9	8	
	Somewhat agree	12	8	
	Strongly agree	25	27	
	Don't know	3	1	
	Total	50	46	

5.3.5. Perceived Barriers

The majority of the subjects did not have barriers to being tested for CBD, including time requirement for the test, blood draw discomfort, and possible effects on their employment (Table 8). None of the three perceived barriers had significant difference between the pre- and post-intervention periods, suggesting that the subjects' perceived barriers to taking the BeLPT did not change after the risk communication.

Table 8. Comparison of Perceived Barriers between Pre- and Post-Intervention Periods

Question	Response options	Pre-int.	Post-int.	Wilcoxon signed rank test
Perceived Barriers 1: <i>I don't have time to get the test done.</i>	Strongly disagree	17	21	P = 0.4786 (n = 45)
	Somewhat disagree	7	2	
	Neither agree nor disagree	18	17	
	Somewhat agree	4	3	
	Strongly agree	3	3	
	Don't know	1	0	
	Total	50	46	
	Perceived Barriers 2: <i>A barrier to my getting tested is that I don't like having my blood drawn.</i>	Strongly disagree	28	
Somewhat disagree		12	3	
Neither agree nor disagree		4	11	
Somewhat agree		3	0	
Strongly agree		2	2	
Don't know		1	1	
Total		50	45	
Perceived Barriers 3: <i>The test result might affect my employment.</i>		Strongly disagree	27	24
	Somewhat disagree	8	7	
	Neither agree nor disagree	4	3	
	Somewhat agree	4	6	
	Strongly agree	1	0	
	Don't know	6	6	
	Total	50	46	

5.3.6. Self-efficacy

Among the five HBM variables, self-efficacy had the most significant changes between the pre- and post-intervention periods. After the risk communication, significantly more subjects felt that they were confident that they have enough information to decide whether to get tested for BeS ($p < 0.0001$). They also felt more confident that they know where and how they can receive the test. P-values for both of the self-efficacy items were less than 0.0001 (Table 9).

Table 9. Comparison of Self-efficacy between Pre- and Post-Intervention Periods

Question	Response options	Pre-int.	Post-int.	Wilcoxon signed rank test
Self-efficacy 1: <i>I feel confident that I have enough information to decide whether I should get tested.</i>	Strongly disagree	6	2	P = < 0.0001 (n = 39)
	Somewhat disagree	7	3	
	Neither agree nor disagree	13	6	
	Somewhat agree	10	14	
	Strongly agree	7	21	
	Don't know	7	0	
	Total	50	46	
Self-efficacy 2: <i>I feel confident that I know where and how to get tested.</i>	Strongly disagree	15	2	P = < 0.0001 (n = 36)
	Somewhat disagree	5	7	
	Neither agree nor disagree	8	7	
	Somewhat agree	7	14	
	Strongly agree	4	16	
	Don't know	11	0	
	Total	50	46	

5.4. Association between the Binary PAPM Groups and Knowledge and HBM Variables

Associations between the PAPM and the six knowledge and HBM variables were analyzed to understand what variables were the key to promoting the screening test in this study population of dental technicians in BC. A two-sample t-test was used to study whether the knowledge levels differ between the Unengaged and Engaged groups. Since the HBM variables had ordinal responses, I used the Wilcoxon rank-sum tests to analyze the association between the binary PAPM variable and each of the five HBM variables.

Four out of fifteen items were found to be associated with the binary PAPM groups at the pre-intervention period (Table 10). The Engaged group had a mean knowledge test score of 66 percent during the pre-intervention period, which was significantly higher than the mean of 40 percent in the Unengaged group ($p = 0.0007$). Perceived severity about CBD was significantly higher in the Engaged than the

Unengaged ($p = 0.0127$). The Engaged also had higher self-efficacy than the Unengaged with regard to having enough information to decide to get tested ($p = 0.0359$). To summarize, the subjects who were engaged with the beryllium health issues knew more about beryllium hazard and CBD, considered CBD more as a serious health condition, and were more confident that they had enough knowledge to make decision about getting tested for CBD.

Table 10. Associations between the Binary PAPM Groups and the Knowledge and HBM Variables at the Pre-Intervention Period

Dependent Variable	P-value	Association
Knowledge	0.0007	Engaged > Unengaged
Perceived Susceptibility 1: <i>How likely is it that you have been exposed to beryllium dust or fumes in your <u>current</u> job?</i>	0.3448	
Perceived Susceptibility 2: <i>How likely is it that you have been exposed to beryllium dust or fumes in your <u>past</u> jobs?</i>	0.0527	
Perceived Susceptibility 3: <i>How concerned are you that you might have become sensitized to beryllium?</i>	0.3794	
Perceived Susceptibility 4: <i>How concerned are you that you might develop chronic beryllium disease?</i>	0.4529	
Perceived Severity 1: <i>How serious do you think sensitization to beryllium is?</i>	0.0527	
Perceived Severity 2: <i>How serious do you think chronic beryllium disease is?</i>	0.0127	Engaged > Unengaged
Perceived Benefits 1: <i>Getting myself tested would let me know if I'm sensitized to beryllium.</i>	0.4612	
Perceived Benefits 2: <i>Getting myself tested would help me know if I should get treatment.</i>	0.0098	Unengaged > Engaged
Perceived Benefits 3: <i>My family would be supportive of my getting tested.</i>	0.1489	
Perceived Barriers 1: <i>I don't have time to get the test done.</i>	0.2658	
Perceived Barriers 2: <i>A barrier to my getting tested is that I don't like having my blood drawn.</i>	0.2482	
Perceived Barriers 3: <i>The test result might affect my employment.</i>	0.3501	
Self-efficacy 1: <i>I feel confident that I have enough information to decide whether I should get tested.</i>	0.0359	Engaged > Unengaged
Self-efficacy 2: <i>I feel confident that I know where and how to get tested.</i>	0.3818	

In contrast, the Unengaged had significantly higher scores than the Engaged in perceived benefit of getting to know their treatment need by getting tested for CBD ($p = 0.0098$). This was an unexpected observation, and reasons for this finding are unknown. None of the perceived susceptibility and perceived barrier items had significant difference between the Engaged and the Unengaged at the pre-intervention period. Knowledge was the only variable associated with the binary PAPM groups at the post-intervention period, where the Engaged had higher test scores than the Unengaged, with the one-sided p -value of 0.0136 (not listed on Table 10).

5.5. Communication Material Evaluation

Finally, the online risk communication materials were evaluated by the survey participants in order to understand whether the materials fit their needs and to improve the communication for future uses. As shown in Table 11, the majority of the participants favored the communication materials and they were satisfied with their learning experience, while a few participants commented that they wanted more detailed information.

Table 11. Evaluation of the Risk Communication Materials by Survey Participants

Questions	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
The educational materials provided me thorough information	21	17	4	1	1
The information provided was useful	30	14	1	0	0
The information was well-organized	27	17	1	0	0
The length of the education materials was adequate	25	14	3	2	1
The learning experience was satisfactory	25	16	3	0	0

6. Discussion

Despite the suspicion of beryllium use in several industries, British Columbia has been left behind on conducting beryllium exposure and disease assessment. As I discovered the lack of awareness about beryllium hazard in BC industries during the Beryllium Study's recruitment process, this risk communication study was developed to raise awareness of CBD in aerospace workers and dental technicians in BC. The study achieved its goal of raising awareness and promoting the screening test in dental technicians, in which survey results show that subjects' levels of knowledge about CBD, perceived severity, perceived benefits, and self-efficacy were associated with the PAPM stages. In contrast, I could not conduct the study with aerospace workers due to the unsuccessful recruitment. In this section, I will discuss the results and several limitations of the study and propose recommendations for future risk communication activities.

6.1. Risk Communication with Dental Technicians: Study Limitations and Alternative Approaches

The small sample size of fifty completed survey responses was one of the major limitations when conducting statistical analysis, especially because the study was arranged to have many categorical variables. With the low response rate of 5.4 percent it is difficult to assume that the study subjects represented the target population. The small sample size may also have reduced the power of the statistical analysis. While I chose to use the online survey tool to invite the entire population to participate in the study, I also believe that in-person communication with the target population should have a better response rate and would engage more people with the topic.

Apart from this risk communication study, I had an opportunity to attend a town hall meeting organized by the Dental Technicians Association of BC (DTA of BC). I gave a brief oral presentation of the Beryllium Study and handed out the study information to a group of about 20 dental technicians. Several participants expressed

their interest in the study and requested additional information after the town hall meeting. Accordingly, I arranged an in-person meeting with four dental technicians. This meeting was very meaningful because not only could I provide more detailed information about BeS and CBD risks and answer their questions but also I gained some insights about beryllium use in BC dental laboratories. All four dental technicians I interviewed have received the BeLPT through this program. I also attended a dental technology convocation, organized by the DTA of BC, and distributed the Beryllium Study information to participants. In addition to the in-person communication, the Beryllium Study information was emailed to members of DTA of BC, and paper copies of the information were distributed with a CDTBC's newsletter to registered dental technicians in BC. While the online communication was an efficient approach to reaching a larger group and raising awareness of CBD in a target population, I found face-to-face communication a more effective means to exchange knowledge and promote the screening test in dental technicians. In conclusion, I recommend a combination of both in-person and remote approaches for future risk communication activities in this population.

All of the above communication activities were done prior to the conduct of this risk communication study. These previous activities may have helped increase awareness of CBD in dental technicians and reflected the survey results that 66 percent of the subjects had some knowledge about CBD at the pre-intervention period (Figure 3). The levels of perceived susceptibility (Table 5) and perceived severity (Table 6) at the pre-intervention period were higher than expected. I suggest that the results of these variable responses might have been lower if I did not distribute the Beryllium Study information prior to the online survey. The significant increase in perceived benefits (Table 7) and self-efficacy (Table 9) of taking the BeLPT supported the effectiveness of the risk communication. Moreover, the results of reasonably low perceived barriers (Table 8) favored the promotion of the BeLPT. The positive association between the binary PAPM groups and knowledge, perceived severity, and self-efficacy suggested that the PAPM was an appropriate model to evaluate the effectiveness of the risk communication.

Another possible limitation in the study design was that the subjects were asked to take the post-intervention survey immediately after reading the risk communication

materials. Although they had the option of saving their responses and completing the survey later, I suspect that many of the subjects did not spend time apart from the survey to think about the health issues and the screening test before starting the post-intervention survey. If there was a time lag between the risk communication and the post-intervention survey, more subjects might have been categorized in the Engaged group, which may have affected the association with the HBM variables. In addition, a larger sample size could also have strengthened the association between the binary PAPM groups and the HBM variables.

Lack of knowledge about individuals' true beryllium exposure risk was also a limitation in this study. The surveys did not ask subjects about the details of their work operation, work history, and materials they had used. Four out of 50 subjects answered "very likely" to the question of how likely it is that they have been exposed to beryllium in their current job, and 17 subjects answered "very likely" to the question regarding their past jobs (Table 5). However, their true exposure history might not be reflected in these responses. These factors should vary greatly and may have affected the results of the PAPM stages and the knowledge and HBM variables.

It is possible that dental technicians might be unaware of their exposure to beryllium. The following exposure assessment illustrates how this might happen. I collected surface wipe samples from five areas of the laboratories that are used by the Dental Technology Program in Vancouver Community College in BC. The analysis of the samples revealed that 0.10 and 0.11 $\mu\text{g}/100\text{ cm}^2$ of beryllium were found in the samples taken from two manual casting machines, while the other three samples did not have any detectable level of beryllium. According to the program's staff and faculty members, the laboratories were closed in 1997 for a major renovation and reopened in 1999 (A. White & L. Chow, personal communication, March 28, 2012). The two casting machines were brought in new after the renovation. The oldest member of the program has worked in the program since right after the reopening of the laboratories, but neither he nor other staff members were aware of any beryllium use in the laboratories. Having no detectable level of beryllium in the other three samples suggests that the beryllium found in the casting machines resulted from use of beryllium-containing materials in the area, and not from naturally occurring beryllium. Therefore, the program staff members and many students have been exposed to beryllium without knowing the sources of the

beryllium exposure and recognizing their exposure risk. I suspect that the actual likelihood of beryllium exposure in dental technicians is higher than the reported level, and there might be many more unrecognized and unintentional beryllium exposure scenarios that put dental technicians at risk of BeS and CBD

The overall findings from the survey results lead to a question of whether the dental technicians' position fits in the precautionary advocacy index of Sandman's risk communication scheme. The reasonably high awareness of beryllium hazard and levels of perceived susceptibility and perceived severity at the pre-intervention period indicate that outrage was higher than expected and the risk-outrage contrast was more balanced. At the same time, although the majority of the dental technicians are now engaged by the issues without having barriers against taking the screening test, the gap between being engaged and taking precautionary action remains. Therefore, the next assignment is to bring those engaged individuals to the "decided to test" stage and the "acting" stage while keeping their outrage level high. One of the suggestions for future risk communication in this population is to introduce more occupation-specific information such as a list of beryllium-containing dental alloys and dental production processes that cause beryllium exposure. Detailed knowledge translation of the effects of beryllium on dental technicians will help them get a better idea of their individual exposure and disease risks and understand the need for beryllium assessment for their workplace and health.

Social marketing is an alternative risk communication theory that has been used in many health promotion activities to achieve behavioral changes. While providing information and the screening test is considered as a "product" that we can offer, we should also consider the other three items of the social marketing perspective to fill the gap: price, place, and promotion (Kotler & Zaltman, 1971). The "price" in the beryllium risk communication refers to the cost of the screening test, traveling expenses to receive the test, effort of allocating time for the test, and physical, psychological, and social burdens. The "place" represents the accessibility of the product, such that we need to arrange the distribution of the product in a way that workers can reach out easily with minimal price to pay. Most of the dental technicians do not have barriers according to the survey results, but there is a scope to improve the accessibility of the screening test. By funding the Beryllium Study, WorkSafeBC provides the product to workers at risk of

beryllium exposure at no charge. Ideally, the screening test should be available to the workers at their convenience through their employment with no or minimal price even after the study is over. Local medical clinics should also be familiar with beryllium health issues and be able to provide proper information and the screening test. Gaining understanding from the employers and doctors is necessary to put these schemes into practice. Finally, I believe the “promotion” of the beryllium information and screening test must be continued for a long term using the various communication approaches that I described before.

6.2. Risk Communication with Aerospace Workers: Recruitment Challenges and Recommendations

The unsuccessful recruitment of aerospace workers was related to lack of evidence of their beryllium use and lack of recognition about their risk of developing CBD from legacy exposure. Learning from the exposure assessment conducted in Vancouver Community College, it is possible that many aerospace workers have been exposed to beryllium without being aware of it. An incident that occurred in Lawrence Livermore National Laboratory, a DOE site in California, U.S., describes an example of the dangers associated with lack of awareness about beryllium exposure. Beryllium waste has been processed in this facility where regular swipe-down cleaning is done only in the area below eight feet (DOE, 2008). Although possible beryllium contamination in the higher levels of the room, including ductwork, was known at the time, the ductwork was removed from the room to another area for a modification without proper handling to prevent exposure (DOE, 2008). This miscommunication among the facility personnel led to an incident of spreading beryllium contamination, exposure and sensitization of workers, which could have been prevented.

Some of the aerospace companies decided not to participate in the Beryllium Study even though they recognized their potential legacy exposures. There are some examples of exposure from legacy beryllium contamination in other DOE sites. Hanford, a DOE site in Washington, U.S. with known beryllium operations since the 1950s to 1986, started their environmental remediation of contaminated areas in the late 1980s (Abbotts, Ertell, Leschine, & Takaro, 2003). At the same time, they decided to lease

their buildings and equipment for commercial reuse. A northern portion of a beryllium-contaminated building that had been previously used for nuclear fuel fabrication was leased to an independent company without conducting a proper assessment for beryllium contamination. Beryllium contamination was found in the leased building a few years after the start of the lease, which indicates the expansion of beryllium exposure and disease risks into workers in a non-DOE company that had subsequently leased the building from DOE (Abbotts et al., 2003). Learning from these DOE examples, since beryllium components are known to have been maintained by BC aerospace workers, some aerospace companies in BC may have put their workers at risk of exposure to beryllium without recognizing the risk. Therefore, continuing risk communication in this population is highly recommended to raise awareness of potential exposure and health risks.

The organization of aerospace companies is very different from that of companies employing dental technicians, in which most dental technicians in BC work in a small dental laboratory or work alone as a self-employee. I found that dental technicians tend to be more familiar with their materials and work operations and take the beryllium health issues more personally than the aerospace company representatives. The major challenge with the recruitment of aerospace workers for this study was that the company representatives were not convinced of the importance of investigating their potential beryllium exposure and having their workers get tested for BeS. Many of the aerospace companies did not seem willing to open themselves for discussion, and I was not able to reach their employees.

In order to overcome the challenge with the recruitment of aerospace workers, we need to develop different risk communication strategies that target their employers. The most essential element is to obtain more knowledge and clear evidence of beryllium use in specific aircraft and aerospace facilities with beryllium-related operations, particularly from past maintenance activities. Then, we should emphasize the importance of investigating their beryllium exposure and disease risks and warn them against failing to identify their risks by introducing the legacy exposure examples. Cost-benefit analysis can be a useful tool in this process. In addition, I believe law enforcement will promote the process. WorkSafeBC is expected to set a new occupational exposure limit soon and conduct further beryllium assessments and risk

communication to protect workers' health. As the new standard is enforced, WorkSafeBC should request companies where current or past beryllium use is suspected to undertake a detailed review of their materials and beryllium-related work operations and to conduct exposure assessments if necessary.

Learning from the in-person communication with dental technicians, direct interaction with individual workers is the most effective way to exchange knowledge and engaged individuals. While making above recommendations that attempt to persuade the employers to participate in beryllium assessment, we should also take the initiative in developing a bottom-up design that will engaged workers and encourage their employers to take action. A possible approach to gaining access to individual worker is to cooperate with workers union, the International Association of Machinists and Aerospace Workers (IAMAW). For example, having a focus group dialogue about beryllium-related health risks among aerospace workers will help us understand their needs and concerns. Some workers may think that determining their beryllium exposure and sensitization status is not beneficial to them because there is not cure for CBD. If we know about such concern among workers, we can emphasize that proper medical treatment and elimination of additional beryllium exposure may slow the progression of CBD and prevent or reduce symptoms. In addition, we should explain how other workers can benefit from one's test results by understanding their potential beryllium exposure and disease risks and making their employers consider workplace management interventions. Then we can plan better communication methods that bring the workers' voices to their employers, constructing triangle communication bridges between service providers, workers, and employers.

7. Conclusion

This risk communication study was designed to educate aerospace workers and dental technicians in BC about CBD and to promote the screening test. The online survey and risk communication were completed by fifty BC dental technicians. Prior to the risk communication, thirty-four percent of them had never heard about beryllium as a health hazard, and 46 percent had some knowledge about CBD but had never thought about getting a screening test. The subjects gained more knowledge about CBD after reading the online risk communication materials and became more engaged concerning the beryllium health issues. Based on the significant shift from being unengaged with the issues to being engaged, the online risk communication was able to successfully raise awareness of beryllium hazards and CBD and promote the BeLPT in the BC dental technicians who participated in this study. Along with their beryllium knowledge, the risk communication also increased subjects' perceived severity, perceived benefits, and self-efficacy.

Knowledge, perceived severity, and self-efficacy were positively associated with the binary PAPM groups. In other words, compared to those who had never thought about getting tested, subjects who had thought about taking a screening test were more knowledgeable about CBD, considered CBD more as a serious health condition, and were more confident that they had enough information to make decision about taking the screening test. The negative association between the binary PAPM groups and one of the perceived benefits was an unexpected observation that subjects who were engaged did not find the screening test as beneficial as the unengaged subjects did in regard to knowing whether they should get treatment. These findings suggest that knowledge, perceived severity, perceived benefits, and self-efficacy are important elements to consider when conducting a risk communication session with dental technicians.

The results of the material evaluation show that the information was delivered successfully and most participants were satisfied with their learning experience. Several

dental technicians have contacted me to obtain more information about the BeLPT after participating in this study. I will follow-up with those who are interested in taking the blood test as part of the Beryllium Study. The overall results support further risk communication with dental technicians that will help them understand their individual risk. We also need to establish a more accessible beryllium information and medical service providing system for workers to put the precautionary adoption into practice. Unfortunately, this study failed to recruit aircraft maintenance workers. Challenges of the recruitment included lack of knowledge about possible use of beryllium in their facilities and some difficulty in convincing their employers of the importance of investigating their workers' potential risk of BeS and CBD. We should develop another set of communication strategies that target employers in order to overcome these challenges with aerospace industry.

Lessons learned from this risk communication study: The PAPM and the HBM are effective tools with which to evaluate risk communication, and continuing communication should be done using remote and in-person approaches so that both target audience and information and service providers can benefit from the knowledge exchange. While gaining more detailed information about where and how beryllium-containing materials have been used in different industries, the importance of investigating uncertain beryllium exposure and disease risks needs to be emphasized when raising awareness of CBD and promoting screening of the workers at risk. In addition, I recommend simultaneous enforcement of policy changes, combined with continuing risk communication to fulfill these tasks. I hope that this risk communication study and the associated recommendations will help promote future beryllium communication activities and contribute to beryllium exposure and disease prevention in BC.

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Appendices

Appendix A.

Questionnaire

Pre-Intervention Survey

1. How old are you?
_____ years old

2. What is your gender?
 - Male
 - Female

3. What is your race or ethnicity? (Check all that apply)
 - White (non-Hispanic)
 - Black (non-Hispanic)
 - Hispanic
 - First Nations
 - Asian
 - Other – specify: _____

4. How many years of education have you had?
(For example: 12 years is completion of high school)
_____ years

5. What year did you started working as Dental Technician?
Year _____
 - I have never worked as Dental Technician – specify your occupation _____

6. Where is your current work place located?
 - Metro Vancouver
 - Lower Mainland outside of Metro Vancouver
 - Victoria
 - Other area of Vancouver Island or Mainland, BC
 - In British Columbia but not in one of the places listed above
 - Other _____

7. Are you aware that beryllium is a human health hazard?

- Yes, I know a lot about it
- Yes, I have some knowledge about it
- Yes, but I don't know anything about it
- No, I have never heard of it until participating in this study

8. What are your thoughts about being tested for chronic beryllium disease?

- I have never thought about being tested
- I have thought about it, but I am undecided about being tested
- I have decided I do not want to be tested
- I have decided I do want to be tested
- I have been tested before and do not plan to be tested again
- I have been tested before and plan to be tested again in the future
- Other _____

9. Have you ever been diagnosed with chronic beryllium disease?

- Yes
- No

10. Have you ever been diagnosed with sarcoidosis?

- Yes
- No

Please do not look up any information about beryllium while you fill out this section. Do not worry about whether your answers are right or wrong.

For each of the following statements, answer whether you believe it is true or false.

	True	False	Don't know
11. Beryllium is a health concern if its dust or fumes are breathed in.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12. Beryllium is a health concern if it contacts skin with an open wound.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13. Exposure to beryllium is safe if the exposure level is kept below the Permissible Exposure Limit.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14. When a person is exposed to beryllium, it is likely that he/she will experience symptoms within a month of the exposure.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
15. Chronic beryllium disease affects the lungs.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16. Chronic beryllium disease is also called sarcoidosis.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17. Chronic beryllium disease is preventable.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18. Chronic beryllium disease is treatable.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19. Chronic beryllium disease is curable.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
20. If the diagnostic blood test result is "normal," it is safe to work with beryllium.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

21. How likely is it that you have been exposed to beryllium dust or fumes in your current job?

- Very likely
- Somewhat likely
- Somewhat unlikely
- Very unlikely
- Don't know

22. How likely is it that you are exposed to beryllium dust or fumes in any of your past jobs?

- Very likely
- Somewhat likely
- Somewhat unlikely
- Very unlikely
- Don't know

23. How concerned are you that you might have become sensitized to beryllium?

- Very concerned
- Somewhat concerned
- Not so concerned
- Not concerned at all
- Don't know

24. How concerned are you that you might develop chronic beryllium disease?

- Very concerned
- Somewhat concerned
- Not so concerned
- Not concerned at all
- Don't know

25. How serious do you think sensitization to beryllium is?

- Very serious
- Somewhat serious
- Not very serious
- Not serious at all
- Don't know

26. How serious do you think chronic beryllium disease is?

- Very serious
- Somewhat serious
- Not very serious
- Not serious at all
- Don't know

Assuming that the diagnostic blood test is available to you at no charge, to what extent do you agree or disagree with the following statements?

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	Don't know
27. Getting myself tested would let me know if I'm sensitized to beryllium.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
28. Getting myself tested would help me know if I should get treatment.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
29. My family would be supportive of my getting tested.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
30. I don't have time to get the test done.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
31. A barrier to my getting tested is that I don't like having my blood drawn.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
32. The test result might affect my employment.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
33. I feel confident that I have enough information to decide whether I should get tested.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
34. I feel confident that I know where and how to get tested.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Post-Intervention Survey

7. Are you now aware that beryllium is a human health hazard?
- Yes, I know a lot about it
 - Yes, I have some knowledge about it
 - Yes, but I don't know anything about it
 - No, I didn't get the information
8. What are your thoughts about being tested for the disease?
- I have never thought about being tested
 - I have thought about it, but I am undecided about being tested
 - I have decided I do not want to be tested
 - I have decided I do want to be tested
 - I have been tested before and do not plan to be tested again
 - I have been tested before and plan to be tested again in the future
 - Other _____

For each of the following statements, answer whether you believe it is true or false.

	True	False	Don't know
11. Beryllium is a health concern if its dust or fumes are breathed in.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12. Beryllium is a health concern if it contacts skin with an open wound.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13. Exposure to beryllium is safe if the exposure level is kept below the Permissible Exposure Limit.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14. When a person is exposed to beryllium, it is likely that he/she will experience symptoms within a month of the exposure.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
15. Chronic beryllium disease affects the lungs.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16. Chronic beryllium disease is also called sarcoidosis.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17. Chronic beryllium disease is preventable.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18. Chronic beryllium disease is treatable.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19. Chronic beryllium disease is curable.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
20. If the diagnostic blood test result is "normal," it is safe to work with beryllium.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

21. How likely is it that you have been exposed to beryllium dust or fumes in your current job?

- Very likely
- Somewhat likely
- Somewhat unlikely
- Very unlikely
- Don't know

22. How likely is it that you are exposed to beryllium dust or fumes in any of your past jobs?

- Very likely
- Somewhat likely
- Somewhat unlikely
- Very unlikely
- Don't know

23. How concerned are you that you might have become sensitized to beryllium?

- Very concerned
- Somewhat concerned
- Not so concerned
- Not concerned at all
- Don't know

24. How concerned are you that you might develop chronic beryllium disease?

- Very concerned
- Somewhat concerned
- Not so concerned
- Not concerned at all
- Don't know

25. How serious do you think sensitization to beryllium is?

- Very serious
- Somewhat serious
- Not very serious
- Not serious at all
- Don't know

26. How serious do you think chronic beryllium disease is?

- Very serious
- Somewhat serious
- Not very serious
- Not serious at all
- Don't know

Assuming that the diagnostic blood test is available to you at no charge, to what extent do you agree or disagree with the following statements?

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree	Don't know
27. Getting myself tested would let me know if I'm sensitized to beryllium.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
28. Getting myself tested would help me know if I should get treatment.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
29. My family would be supportive of my getting tested.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
30. I don't have time to get the test done.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
31. A barrier to my getting tested is that I don't like having my blood drawn.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
32. The test result might affect my employment.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
33. I feel confident that I have enough information to decide whether I should get tested.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
34. I feel confident that I know where and how to get tested.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

At last, we would like to get your feedback on the educational materials.

To what extent do you agree or disagree with the following statements:

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Strongly disagree
35. The educational materials provided me thorough information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
36. The information provided was useful	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
37. The information was well-organized	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
38. The length of the education materials was adequate	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
39. The learning experience was satisfactory	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

40. Did you go to the beryllium study website listed on the educational materials for additional information?

- Yes
- No

41. Thinking about what was more or less valuable about the information provided, what would you add/change about it?

42. Would you like to receive more information about how to receive the beryllium lymphocyte proliferation test?

- Yes → Please request information by emailing Yu Uchida at yu@sfu.ca
- No

43. Do you have any comments?

Appendix B.

Risk Communication Materials

What is Beryllium?



Metal used in a wide range of industrial & consumer products

Examples:

- nuclear reactors
- aircrafts & automobile
- dental crowns and bridges
- fluorescent lights
- computers
- electronics
- golf clubs
- bike frames
- Jewellery



Photos by Yu Uchida

Properties:

- Very strong
- Light-weight
- Conduct heat well
- Transparent to X-rays
- Reflect neutrons

Forms:

- Raw metal
- Alloys
- Ceramic (Beryllia)

5/22/2012

1

Chronic Beryllium Disease (CBD)

A lung disease caused by breathing in beryllium dust or fumes or by having skin with open wound contact beryllium.

Routes of Exposure:

- Inhalation
- Skin Contact

- CBD causes inflammation and scarring in the lung.
- CBD can be fatal.
- There are many CBD cases found in workplaces where the exposure levels are below the Permissible Exposure Limit for beryllium (0.002 mg/m³ of the air).
- CBD is often misdiagnosed as sarcoidosis unless a specific blood test is performed.

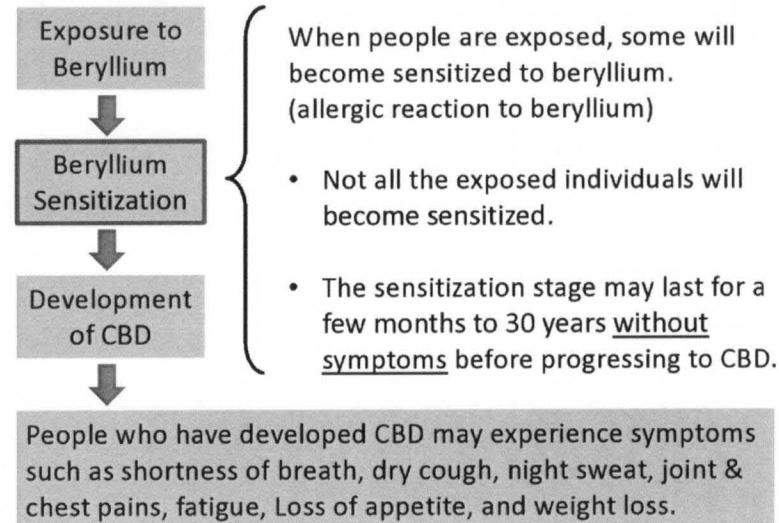
Who are at risk?

People who have worked with beryllium, who have spent time in beryllium work areas, and family members of beryllium-exposed workers

6/20/2012

2

Development of Chronic Beryllium Disease



5/22/2012

3

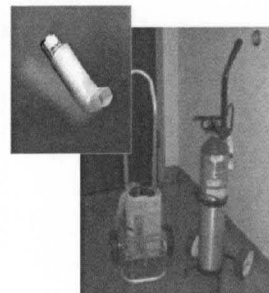
Prevention & Treatment of CBD

CBD can be prevented by eliminating beryllium exposure. (e.g. material substitution, engineering control, personal protective equipment)

- There is no "safe" level of exposure. Even though the amount of beryllium used in dental alloys may be small (ranging from 0.05 - 2%), there is still a risk of developing beryllium sensitization or CBD.

CBD can be treated to slow progression of the disease.

Disease Stage	Treatment Example
CBD with no symptoms	No treatment needed
CBD with mild symptoms	Steroids Inhaled medication
CBD with severe symptoms	Oxygen therapy



Photos by National Jewish Health

CBD is not curable at the present time.

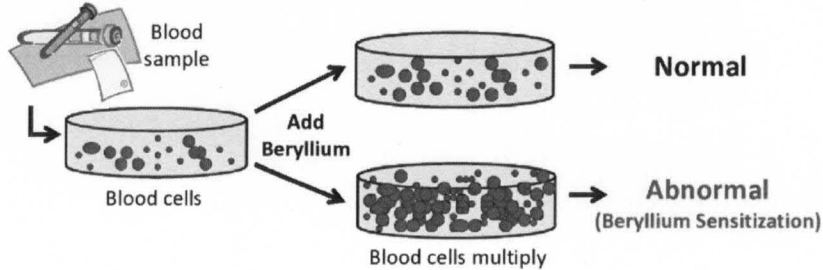
5/22/2012

4

Diagnostic Blood Test

Beryllium Lymphocyte Proliferation Test (BeLPT)

--- Detects whether an individual is sensitized to beryllium.



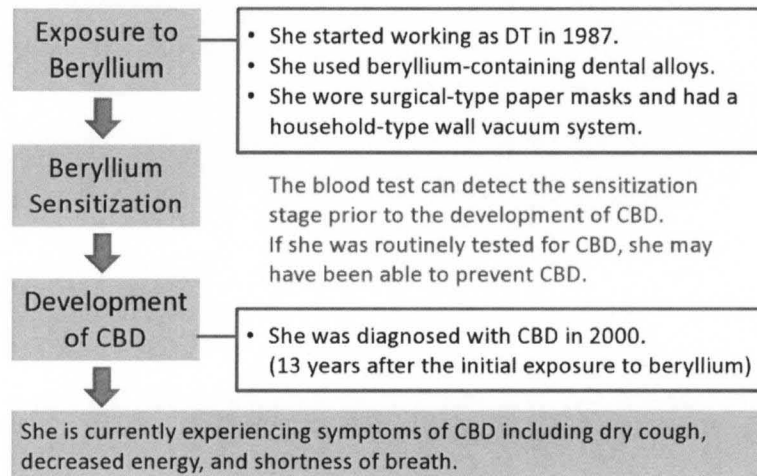
- Even if the result is “normal,” it is not safe to work with beryllium.
- Beryllium sensitization is confirmed when the person has 2 or more abnormal BeLPT results. Further medical evaluation is recommended for CBD diagnosis.

5/22/2012

5

Disease Case Example

A 53-year-old dental technician diagnosed with chronic beryllium disease



5/22/2012

Preventing Adverse Health Effects From Exposure to Beryllium in Dental Laboratories
OSHA Health Information Bulletin <http://www.osha.gov/dts/nib_data/nib20020419.html>

6

Who should get tested?

All individuals who have ever been exposed to beryllium.

The blood test (BeLPT) is recommended if you:

- directly work with beryllium,
- used to work with beryllium in the past,
- have worked in beryllium exposed area

Why should I get tested?

Early diagnosis is the key.

If beryllium sensitization or CBD is diagnosed early and treated correctly, the patient may not experience any symptoms for a life time.

5/22/2012

How to get tested?

A research group at Faculty of Health Sciences, Simon Fraser University, is conducting a study about chronic beryllium disease in British Columbia. For more information about the study, visit www.sfu.ca/bestudy

If you suspect that you have been exposed to beryllium and wished to take the diagnostic blood test, please contact:

Yu Uchida
Research Assistant
778-782-2273
yu@sfu.ca

The test may be provided to you at free of charge.